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Docket: 137501

In The United States Patent & Trademark Office

Applicant:	Shubhra Venna	Group Art Unit:	2611
Application No.:	10/743,690	Examiner:	Julia P. Tu
Filed:	12/19/2003	Confirmation No.:	7790

Title: SYSTEM AND METHOD FOR DIGITAL TRANSMISSION AND MODULATION OF CONJUGATE PULSE POSITION

CERTIFIED COPY OF APPLICATION FOR FOREIGN PRIORITY

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Sir:

Under the provisions of 35 U.S.C 119 and 37 CFR 1.55, applicant claimed the right of priority based on Indian Application 1296/DEL/02 filed on December 24, 2002.

In response to the examiner's request, a certified copy of the above Indian Application is attached hereto.

Dated: 25 June 2007

Respectfully submitted,

By: ____________
Ellis B. Ramirez (45,326)

Certificate of Mailing

I hereby certify that this correspondence is being mailed to the United States Patent and Trademark Office through Express Mail No.**ED-163663535-US** on 25 June 2007.

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I, the undersigned being an officer duly authorized in accordance with the provision of the Patent Act, 1970 hereby certify tha+9t annexed hereto is the true copy of the ***Application, Complete Specification and Drawings*** *filed in connection with* ***Patent Application No.1296/Del/2002 dated 24th December, 2002***

Witness my hand this 18th day of May, 2007

(N.R.Meena)
Assistant Controller Of Patents & Designs

Govt. of India Patent Office
New Delhi
Received Rs. [illegible] in cash
[illegible]
24 DEC 2002
Vide Entry No. 3 [illegible] in the
Register of Valuables

1296 DEL 02

24 DEC 2002

FORM 1
THE PATENTS ACT, 1970
(39 OF 1970)
Application for Grant of a Patent
[See Sections 5(2), 7, 54 and 135 and rule 33A]

H03K 7/04

1. We

1. **Professor S.K. Kak**
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S-15/135, A-3, Mawaiya
Sarnath, Varanasi – 221 007.

ORIGINAL

2. Hereby declare -
   (a) that we are in possession of an invention titled **CONJUGATE PULSE POSITION MODULATION**
   (b) that the complete specification relating to this invention is filed with this application.
   (c) that there is no lawful ground of objection to the grant of a patent to us.

3. Further declare that the inventor(s) for the said invention are:

1. **Professor S.K. Kak**
c/o Banaras Hindu University
Institute of Technology
Department Electronics Engineering
Banaras Hindu University
Varanasi 221005
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Also at:

S-15/135, A-3, Mawaiya
Sarnath, Varanasi – 221 007.
Indian

4. We, claim the priority from the application(s) filed in convention countries, particulars of which are as follows:

   Not Applicable

5. We state the said invention is an improvement in or modification of the invention, the particulars of which are as follows and of which we are the applicant/patentee:

   Not Applicable

6. We state that the application is divided out of my/our application, the particulars of which are given below and pray that this application deemed to have been filed:

   Not Applicable

7. That we are the assignee or legal representative of the true and first inventors.

8. That our address for service in India is as follows:
   Dinesh Jotwani, Patent Attorney
   B-14, Dayanand Colony
   Lajpat Nagar
   New Delhi – 110 024
   India
   Indian

9. Following declaration was given by the inventor(s) or applicant(s) in the convention country:

I/We the true and first inventors for this invention or the applicant(s) in the convention country declare that the applicant(s) herein is/are/ my/our assignee or legal representative

Not Applicable

10. That to the best of my/our knowledge, information and belief the fact and matters stated herein are correct and that there is no lawful ground of objection to the grant of patent to me/us on this application.

11. Following are the attachment with the application :
    (a) Complete specification (3 copies).
    (b) Drawings (3 copies).
    (c) Declaration as to inventorship
    (d) Power of authority
    (e) Fee of Rs. 1,500/-.in bank draft no. 523217 dated 4.12.2002 drawn on State Bank of India.

We request that a patent may be granted to me/us for the said invention.

Date December 24, 2002

Authorized representative
of the Applicants

To
The Controller of Patents,
The Patent Office,
at New Delhi

1296-DEL-02

24 DEC 2002

FORM 2
THE PATENTS ACT, 1970
(39 OF 1970)
Complete Specification
[See section 10]

TITLE OF THE INVENTION : **CONJUGATE PULSE POSITION MODULATION**

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Sarnath, Varanasi – 221 007.

The following specification particularly describes the nature of the invention and the manner in which it is to be performed:

1296DEL02

24 DEC 2002

Conjugate Pulse Position Modulation

BACKGROUND

Field of the invention

The present invention generally relates to fiber optic communications method and system, and more particularly information transmission technique that provides for passing of large information by exploiting the conjugate signal space.

Description of the related Art

Since the early days of electronics, as advances in technology were taking place, the boundaries of both the local and global communication began eroding, resulting in a world that is smaller and accessible for knowledge and information. Traditionally, local communication was done over wires. However, the wires (coaxial cable systems) for transmitting signal are inherently subject to large line losses when transmitting analog information. The distance between the analog signal source and the receiver or receivers must, therefore, be kept small or appropriate amplification must be provided. These restrictions effectively prevent the use of coaxial systems for long-distance transmission purposes.

Optical fiber systems have also been used to transmit high frequency analog signals and they offer the significant advantage of low line loss over cable systems. A typical loss figure for an optical fiber system is .5 dB per 1000 meters and the distance between the signal source and receiver may be as high as 10 to 30 kilometers without the necessity for amplification.

The various modulation techniques offered different solutions in terms of cost-effectiveness and quality of received signals but until recently were still analog. Various modulation techniques are used to encode digital information in an analog world. The 3 basic modulation techniques are a) AM (amplitude modulation), b) FM (frequency modulation), c) PM (phase modulation). All 3-modulation techniques employ a carrier signal. A carrier signal is a single frequency that is used to carry the data. For digital, the data is either a 1 or 0. When we modulate the carrier, we are changing its characteristics to correspond to either a 1 or 0. FM (frequency modulation) and PM (phase modulation) presented certain immunity to noise, whereas AM (amplitude modulation) is simpler to demodulate.

However, more recently with the advent of low-cost micro-controllers and the introduction of domestic mobile telephones and satellite communications, the digital modulation has gained in popularity. With digital modulation techniques come all the advantages that traditional microprocessor circuits have over their analog counterparts. Any shortfalls in the communication link can be eradicated using software. Information, can now be encrypted, error correction can ensure more confidence in received data. As with the traditional analog systems, digital modulation can use amplitude, frequency, or phase modulation with different advantages. As frequency and phase modulation techniques offer more immunity to noise, they are the preferred scheme for the majority of services in use today.

The two modulation techniques ---- Pulse Code Modulation (PCM) and Digital Pulse Position Modulation (DPPM)-- are well known in the prior art. Pulse Code Modulation (PCM) is commonly used for communications. For example, much of the telephone data (voice, video) that is transmitted digitally is transmitted with the data in PCM format over telephone lines. At research level - DPPM is the most advance and best proposed techniques. DPPM actually consumes more bandwidth than that required by PCM for equivalent information transmission, but improving the receiver sensitivity by about 5-11 Db, when compared to PCM.

The challenge of optimal utilization of optical fiber capacity is to find a modulation format capable of exploiting not only its enormous information carrying capacity but also its full spectral width. In this context, the pulse time modulation (PTM) family has been used to trade bandwidth against noise performance and has utilized the general pulse analog transmission over fiber. The abundance of bandwidth available in mono-mode fibers, operating near the wavelength of minimum chromatic dispersion, is traded for improved receiver sensitivity compared to other existing pulse modulation schemes for synchronous transmission. Using low duty cycle high peak power modulation pulse's enables sending of coded signals over large distances with very low average power and high noise tolerance and better channel efficiency. Significantly larger information can be packed into each pulse in digital pulse position modulation when M is very large. As the demand for high-speed data access keeps on growing, Gigabit transmission systems (Gbit/s) are already in commercial use today for trunk line networks, and next-generation 10's of Gbit/s system are being selectively deployed.

Higher and higher data rate transmission systems are being evolved, as they are needed to satisfy the exponential growth of applications and their users. Various modulation techniques are used to obtain higher data rate for transmission and discussed in some of the following issued patents:

US patent no 6,185,346 titled "Propagation in lowest order modes of multimode graded index fiber, resulting in; very low transmission loss, low modal noise, high data security, and high data rate capabilities" issued to Charles K. Asawa, Jane K Asawa, Mike H. Asawa relate to optical fiber communication systems where data light is launched into a very small set of the lowest order propagation modes of multimode graded index fibers, resulting in very high data rate transmission capability. Added advantages are: low transmission loss, low modal noise, and data security.

US patent no 6,362,903 B1 titled "Use of Higher Order Modulation techniques to transmit information on passbands of a dispersion-limited fiber link" assigned to Lockheed Martin Corporation is a system and method for employing higher order modulation techniques to transmit information on passhands of a dispersion-limited fiber optic communication link. This invention transmits data on previously unused passbands of the dispersion-limited optic link, thus increasing the total capacity of the link.

U.S. Patent No. 5042086, titled as "Method and means for transmitting large dynamic analog signals in optical fiber systems" assigned to Dylor Corporation provides for a method and apparatus is provided for transmitting a broad dynamic range of rf or microwave signals from a source of such signals, e.g. an antenna, to a remotely located receiver, e.g., a television or radar receiver, by phase modulating a beam of light, detecting and demodulating the optical signal to recover the rf or microwave analog signal, and using the recovered signal at the output receiver.

US patent no 5,883,925 titled "Pulse code modulation compression mechanism" assigned to International Business Machines Corporation is a system and method for employing higher order modulation techniques to transmit information on passhands of a dispersion-limited fiber optic communication link. This invention transmits data on previously unused passbands of the dispersion-limited optic link, thus increasing the total capacity of the link.

However, all the above-mentioned issued patents have one or more limitations of the current digital modulation techniques, i.e., it is unable to exploit the conjugate signal space. In view of the above-mentioned shortcomings existing in current digital modulation techniques, a new form of pulse time modulation is required that exhibits superior characteristics in data rate, improved channel utilization and higher coding efficiency.

OTHER REFERENCES

1. Ian Garrett, 'Digital Pulse-Position Modulation for Transmission Over Optical Fibers with Direct or Heterodyne Detection' IEEE Trans., 1983, COM-31, pp518-527

2. R.A. Cryan, R. T. Unwin, A. J. M. Massarella, M. J. N. Sibley and I. Garrett, 'Coherent detection : n-ary PPM vs. PCM' SPIE Proc. On Coherent Lightwave Communications, San Jose, Calfornia, 16-21 September, 1990

3. N. M. Calvert, M. J. N. Sibley and R. T. Unwin, 'Experimental Optical Fiber Digital pulse-Position Modulation System' Electron. Lett. 1991, 27, pp.1953-1954

SUMMARY

It is an object of the present invention to provide for modulation technique, which while giving lesser number of bauds per character is able to have improved noise performance.

Another object of the present invention is to provide for modulation technique that allows for transmission of large information with less transmission energy losses.

Another object of the present invention is to provide for a modulation technique that exploits the conjugate signal space in a Digital Pulse Position Modulation (DPPM) format.

Yet another object of the present invention is to provide for method and system that exhibits superior characteristics in data rate, improved channel utlilization characterstics and having higher coding efficiency.

The present invention is a new form of pulse time modulation scheme, termed Conjugate Pulse Position Modulation (CPPM) that exhibits superior characteristics in data rate, having improved channel utilization characteristics & higher coding efficiency

compared to PCM. The present invention enables sending of coded signals over large distances with very low average power and high noise tolerance and better channel efficiency. Significantly larger information can be packed into each pulse in digital pulse position modulation.

These and other objects, features, functioning and advantages of the present invention will become readily apparent from the attached drawings and the detailed description of the preferred embodiments that follow.

BRIEF DESCRIPTION OF THE DRAWINGS

The preferred embodiments of the invention will hereinafter be described in conjunction with the appended drawings provided to illustrate and not to limit the invention, wherein like designations denote like elements, and in which:

Figure 1 is Encoding Difference between PCM and CPPM modulation technique with pulse transmission for 8 bit data input.

Figure 2 is BER performance comparison results for PCM & CPPM encoder.

Figure 3 is a block diagram of CPPM system in accordance with a preferred embodiment of the present invention.

Figure 4 is a block schematic of analog implementation of CPPM coder in accordance with a preferred embodiment of the present invention.

Figure 5 shows the forward and conjugate pulse generated for encoding forward & conjugate pulse as per the input data.

Figure 6 is a block diagram of the CPPM demodulator in accordance with a preferred embodiment of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention is directed to a system and method for providing a modulation technique having both power and data range efficiency. This technique called, 'Conjugate Pulse Position Modulation' (CPPM) utilizes multiple Digital Pulse Position Modulation (DPPM) format, whereby M data bits are conveyed by splitting them into sets of k bits. By positioning a single pulse as a representative code for every set of k - bits, it sends only N = M/k pulses for M bits of data. As is well known DPPM actually consumes more bandwidth than that required by Pulse Code Modulation (PCM) for equivalent information transmission, but improving the receiver sensitivity by about 5-11 dB, when compared to PCM. However, if we can improve upon the DPPM bandwidth requirement without sacrificing its sensitivity advantage it would be much better to use CPPM, in comparison to PCM which is universally used today.

Figure 1 shows the input data representation by PCM and by CPPM for the same input data. As the CPPM modulator splits M bit digital data into sets of k bits and every set of k - bits it then encodes by one unique pulse in one of the $n = 2^k$, thus it sends only N pulses for M bits. The symbol interval termed as time slot T_n subdivided into n sub slots each of width T_n / n. If N for example is chosen as 2, then the, upper M/2 bits can be coded by having one pulse in forward direction of width τ_f occupying any of the 'n' sub-slots. While the lower M/2 bits can be coded by another pulse of width τ_r again occupying any of the same 'n' sub-slots, but in a conjugate manner.

The CPPM Time domain equation of a typical message $f_n(t)$ is give by :

$$S_{CPPM}(t)=\sum_{k=0}^{n-1} A\tau_f q\, t - kT_s - k_{CPPM} f_n(t_{k_f})\big] + \sum_{k=n-1}^{0} A\tau_r q\big[t - kT_s - k_{CPPM} f_n(t_{k_r})\big] \qquad (1)$$

where, $q(t)$ = arbitrary coded pulse shape of amplitude A,

τ_f and τ_r = forward & conjugate code pulse duration, &

t_{k_f} & t_{k_r} = position of occurrence of the forward & conjugate code pulse.

The above time domain equation (1) is based on the following assumptions:

A) The input data of M-bit width is having even number of bits, which can be divided into N segments of k-bits each;

B) The forward and conjugate coded pulses can occupy the orthogonal 0 to (2^k-1) and (2^k-1) to 0 time positions respectively;

C) All the 'n' sub-slots will be jointly occupied at sometime by the forward and conjugate code pulses during the coding of the full M-bit input data sequence

D) The identity of the forward and conjugate code pulse is based on the different pulse widths τ_f & τ_r respectively, except when both these pulses are co-located when it will be identified by a different pulse width τ_c the common code pulse.

For a CPPM system encoding P information signals each of bandwidth B_f using M bits per sample, the basic data rate is given by

R= P ω_s M , where ω_s is the sampling rate per input channel and for Nyquist rate is 2 B_f .The CPPM encoding rate R_c will be different and given by:

$R_c = 2P\,N\,B_f$;

This data rate will be the upper bound while actually its rate shall be lower by a value 'n'. The frame duration is fixed and given by 'sampling interval / no. of information channels'

$$T_n = 1/\,P.\,\omega_s = 1/\,2\,\pi P f_s$$

For sampling frequency f_s = 8kHz & M = 8-bit data transmission /sample

Data rate / channel = M f_s = 64kbps

No. of information channel P = 16

The slot duration = $1/Pf_s$ = ts/16=7.8us

Sub-slot duration 'τ_n'= Frame interval/2^k = T_n / 2^k = 7.8us/16 = 488ns

Transmission data rate = (data rate/ channel)*(no. of information channel) =Nfs*P = 2.048Mbps for the example taken.

While it is true in general that any processing of a signal results in degradation and contamination of that signal, it is also true that in digitization process the degradation is controlled in such a manner as to provide a fixed grade of service to the user. The Errors introduced at the coder end are:

a) due to amplitude quantization;

b) due to jitter in time discretization. Process;

By the very nature of the CPPM signal, where information is carried by discrete positioning of a pulse pair to represent the corresponding code the time interval between successive pulses will be random, making synchronization of a fixed frequency clock

difficult. However, to decode the received data without any error, the receiver has to be synchronized with the transmitter by deriving the embedded clock information in the coming data stream, which is the CPPM pulse stream in our case. At an instant relative to this clock signal, the received pulse position may be shifted from the transmitted one, either because of noise or due to clock instability or mismatch. Assuming that the noise is additive white Gaussian, the CPPM is subject to same or similar sources of error as in the case of DPPM [2].

a) due to pulse being decoded in the slot other than in which it was transmitted, called the wrong slot error (probability of error of which is denoted by P_r);

b) due to noise crossing the detector threshold and wrongly indicating the presence of the pulse before the actual position it was transmitted in, this is termed as false alarm error with probability P_f;

c) due to noise causing the transmitted pulse to be suppressed below the detector threshold, and will be known as erasure error with probability P_e

CPPM encoder uses a thin pulse for forward pulse position coding and a relatively thicker pulse for conjugate pulse position coding, to allow the decoder to discriminate between these two pulses.

This discrimination can also lead to decoding errors if the pulse widths are affected by noise The average error probability in forward Pulse Position system and in conjugate Pulse Position encoding can be assumed to be orthogonal and using the same 'n' available positions is:

$$P_{ef} = \frac{1}{n}\sum_{k=1}^{n} P_s(k) \qquad \ldots\ldots (2)$$

and $$P_{ec} = \frac{1}{n}\sum_{j=n}^{1} P_s(j) \qquad \text{.......(3)}$$

respectively, further assuming that all positions are equally probable

The average error probability for common slot error with n different symbols, is given by

$$P_{ecs} = \frac{1}{n}\sum_{j=n}^{1}\sum_{k=1}^{n} P_s(k,j) \qquad \text{.......(4)}$$

For a forward pulse placed in slot k and assuming that the joint probability of an erasure and a false alarm is negligible is:

$$P_s(k) = P_s + (k-1)P_f$$

For a conjugate pulse placed in slot j, again assuming that the joint probability of an erasure and a false alarm is negligible and is given by

$$P_s(k) = P_r + P_s + (j-1)P_f \qquad \text{.......(5)}$$

For a common slot error (i.e. forward pulse slot k & conjugate pulse slot j being same), and considering the joint probability of forward & conjugate pulse slot (k, j). Erasure error for joint conditional probability for common slot is given by

$$P_{ecs}(k) = P_r + P_s + (j-1)P_f + (k-1)P_f \ldots(3.39)$$

$$= P_r + P_s + \frac{(n-1)}{2}P_f + \frac{(n-1)}{2}P_f \qquad \text{.......(6)}$$

from which the average bit error probability P_{eb} is determined as

$$P_{eb} = \left(2^{n-1} - n\right)P_{ef} + \left(2^{n-1} - n\right)P_{ec} + 3nP_{ecs}$$

$$= \left(2^{n-1} - n\right) \qquad \ldots\ldots(7)$$

Besides the above stated error sources leading to BER in the decoded data stream their combinations can also occur which have been included in the above analysis, as they shall be orthogonal. Further, the pulse width based discriminator used to decode the forward and conjugate code position can also lead to BER as these widths can be in error due to pulse broadening or contraction effects of noise. However, these widths can be so selected as to have high robustness to this code aliasing. It must also be clarified that the common slot coding pulse width cannot occur with any other pulse and hence if that situation arises it will be recognized as a code violation and hence corrected by the decoder logic.

In order to evaluate the BER performance of the CPPM system, simulation of the system was carried out using Matlab Script, for 8-bit input data and with additive white Gaussian noise introduced in the channel modal. The BER performance of the CPPM system simulation was carried out on Binary Symmetric Channel.

Figure 2 shows the simulated BER performance results of the CPPM system. The CPPM performance is seen to be clearly superior to that of the PCM system above 17 dB input SNR range, but inferior to it below this value. This justifies its use and efficacy in low error rate environment of Optical Fiber systems.

For M bits/sample transmission, having sampling frequency f_s requirements of CPPM are compared to DPPM and PCM as following:

Parameter	CPPM	PCM	DPPM
Minimum Bandwidth	$nN\omega_f$ where, $n = 2^{M/N}$	$NM\omega_f$	$nN\omega_f$ where, $n = 2^M$
Data rate/channel	Nf_s bits/s	Mf_s bits/s	Mf_s bits/s
Transmission data rate	PNf_s	PMf_s	Pf_s
Frame time=Samp. Time/ inf.ch.	t_s / P	t_s / P	t_s / P
Max. No. of pulses/frame	N	M	1
Bit duration	Variable	fixed	fixed
No. of information channel	P	2P	1
Avg. no. of pulses Tx/Sample	< N	M/2	1
Lower bound	N/2(common slot)	0	1
Upper bound	N.	M	1
Code word length	$NP(2^{k+1} - 1)$	M/2	1

The comparative values of operational parameters of CPPM with commercial E1 type PCM transmission system are:

	CPPM	**PCM**
No of bits/Sa	8	8
Data rate/Ch.	N*fs=16kbps	M*fs=64kbps
No of info. Ch.	16	32
slot duration	ts/16 = 7.8us	ts/32 = 3.9us
no.of positions/frame	16	8
bit duration	7.80us/16=488ns	3.9us/8=488ns
Tx.Data Rate	Nfs*16=2.048Mbps	Mfs*32=2.048mbps
Min. tx. BW reqd.	2,048 MHz	2.048 MHz
average no.of pulse	1.9375	
transmission/Sa	2	4

Lower bound	1	0
Upper bound	2	8
Code word length	1.9375<2	4

Figure 3 is a block diagram of CPPM system in accordance with a preferred embodiment of the present invention. The system implementation is done such that, for M bits/sample digital data is split into 'N' sets of k-bits/sample data chunks. For every set of k-bits it generates a time coded pulse, thus it will have to send N pulses for M-bits. Now each of these coded pulses, which represent k-bits of data by its time position within the intra sample time, will have to be transmitted within the same time space. Thus N such pulses will occupy the intra sample duration. The first k-bit representative pulse will be positioned in the normal forward manner. The second k-bit pulse will be however be positioned on the conjugate pulse location within the same space. If the same transmission bandwidth requirement is imposed, then k should be chosen such that, for any value of M-bit transmission N=M/k is a constant. Thus the number of sub-slots remains for all N sets 2^N, now if the pulse width is also same, hence, bandwidth requirement will also be same. For example, for 8-bit digital data, if k is chosen to be 2 then N = 4. Hence at every sample instant of time t = 0 coding will takes place for both forward & conjugate pulse positioning, which when combined together will produce the desired CPPM signal.

CPPM modulator and demodulator design may be formulated around analogue-to-digital (ADC) and digital-to-analogue (DAC) converters on proposed architecture as shown in this figure. There can be various implementation strategies for the CPPM encoding based on analog-digital mixed circuit or all-digital circuit design. One can chose any one of these techniques to meet the required grade of performance and design complexity.

The receiver necessarily has to recover the original base band message from the encoded CPPM signal. It basically performs the inverse operation of the transmitter. The first operation involves that the noise contaminated incoming CPPM waveform at the receiver input has to be detected at the correct sub-slot location. The next operation involves de-multiplexing the CPPM pulse stream into corresponding sub-slot positions and then reconstructing the originally transmitted signal sample from the pulse position data as accurately as possible. All these operation are straightforward, and are just the inverse of those performed in the transmitter.

Figure 4 is a block diagram of analog implementation of CPPM Coder in accordance with a preferred embodiment of the present invention. As shown in the figure a trailing edge digital pulse width modulated signal is generated by comparing the sampled signal against a negative slope linear staircase signal occupying the same intra sample time span. In a similar but conjugate manner a leading edge PWM signal is generated, here the reference staircase is of positive slope having the same number of steps and again occupying the same time frame. Generating the position indicating pulse for each of the N modulated edges of DPWM signals is the next step. These are then multiplexed into the forward and conjugate positioned pulses of different pulse widths (required to identify the pulses at receiver end). However, a special situation when the forward and conjugate pulse is co-located has to be separately coded. This common slot coding has been taken care of by having a third pulse width, which is different and larger, compared to forward and conjugate pulse code widths.

A typical naturally sampled forward PPM modulator is very similar to a trailing edge DPWM modulator, and consists simply of a comparator detecting equivalence between the input signal and a negative slope staircase signal followed by a negative edge triggered mono-stable. The high frequency constant step staircase generator is the critical part of the CPPM transmitter since a linear voltage-to-pulse position conversion characteristic is desired. In the same manner generating the leading edge digital pulse width modulated signal followed by a positive edge triggered mono-stable (pulse

generating circuit) i.e. differentiating the modulated edges of leading edge DPWM, conjugated positioned pulses can be generated. There are various techniques of generating positive slope staircase signals for leading edge DPWM, the technique used here, is based on charging a capacitor with a constant current source through a programmable timing generator controlled high frequency switch.

Figure 5 shows the forward and conjugate pulse generated at the mono-shot pulse generator.

Figure 6 is a block diagram of the CPPM demodulator in accordance with a preferred embodiment of the present invention. Demodulation is achieved by first de-multiplexing the CPPM forward & conjugate pulses within the symbol interval. Sorting and identifying the forward, conjugate and co-located pulses and then decoding them to get the original coded digital data. This decoded data is then converted into analog base band signal using a DAC followed by a low pass filter. However, for de-multiplexing and decoding the CPPM input signal it is essential to have access to an accurate clock signal at the receiver. Clearly, clock pulses could be transmitted with the data pulses, either in every unit interval or at some less frequent intervals. These timing pulses could be separated in the receiver by a dedicated logic, so that the timing signal is not corrupted by 'message noise'. The drawback of this scheme is that the transmission overheads are high, compared to a system implemented without clock signal transmission. Further since the transmitted pulses also carry the clocking information, albeit indirectly they can be used to derive the clocking information. Therefore the receiver has to have a separate block to extract the clock information from the received data stream using a clock recovery technique, and de-multiplex & decode the data using this extracted clock from a PLL or a PLL based recovery system.

Decoding the CPPM signal is relatively more complex when compared with DPPM. It is performed by discriminating between the forward & conjugate pulses in the

CPPM signal and then counting the number of discrete time slots between start of symbol boundaries & rising edge of each of the coded pulses. The recovered slot clock is used to generate the sampling points and count the number of discrete time slots between start of symbol slot & rising edge of decoded pulse. Positive edge of the sampling pulse recovered from CPPM signal through DPLL is used to load the value of the counter into the data latch, and the positive edge of the discriminated CPPM pulses is then used to reset the counters. DAC is used to convert the digital data into analog signal followed by the LPF to recover the analog base band signal.

While the preferred embodiments of the invention have been illustrated and described, it will be clear that the invention is not limited to these embodiments only. Numerous modifications, changes, variations, substitutions and equivalents will be apparent to those skilled in the art without departing from the spirit and scope of the invention as described in the claims.

What is claimed is:

1. A fiber optic communication system, comprising:

Either an analog or a digital input source where the analog input is converted into equivalent digital word using an ADC;

a modulator that splits M bits/sample digital data into 'N' sets of k-bits/sample data chunks;

encoder for forward and conjugate pulse position over the transmission channel that encodes the k-bits per sample into N pulses;

a transmission channel;

a decoder for discriminating between the forward and conjugate pulses in the input data stream; and

a demodulator to combine the forward and conjugate pulses into M-bit digital output and a DAC to convert the input digital data into corresponding analog output.

2. A method for transmitting digital data at high data rate in a fiber optic communication system including:

splitting of M bits/sample digital data into 'N' sets of k-bits/sample data chunks;

modulating the M bits/sample digital data into 'N' sets of k-bits/sample data chunks;

encoding forward and conjugate pulse position over the transmission channel to discriminate between the two pulses;

decoding for discriminating between the forward and conjugate pulses in a signal; and

demodulating the data to combine the forward and conjugate pulses into M-bit digital output.

ABSTRACT OF THE DISCLOSURE

A new form of pulse time modulation scheme, termed Conjugate Pulse Position Modulation (CPPM) is introduced, exhibiting superior characteristics in data rate, having improved channel utilization characteristics & higher coding efficiency compared to PCM. The present invention enables sending of coded signals over large distances with very low average power and high noise tolerance and better channel efficiency. Significantly larger information can be packed into each pulse in conjugate pulse position modulation.

DATE December 24, 2002

AUTHORIZED REPRESENTATIVE OF APPLICANTS

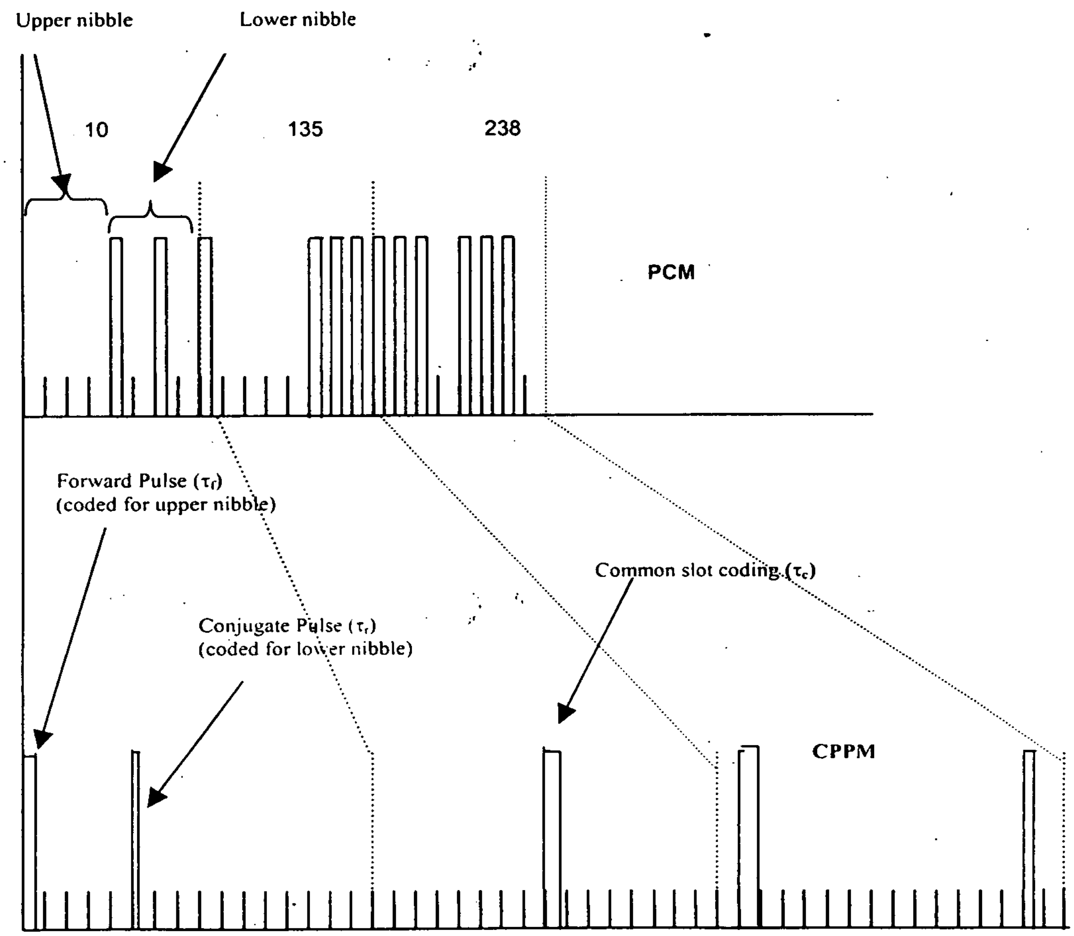

Figure 1: PCM & CPPM Encoding Difference in the Available Time periods

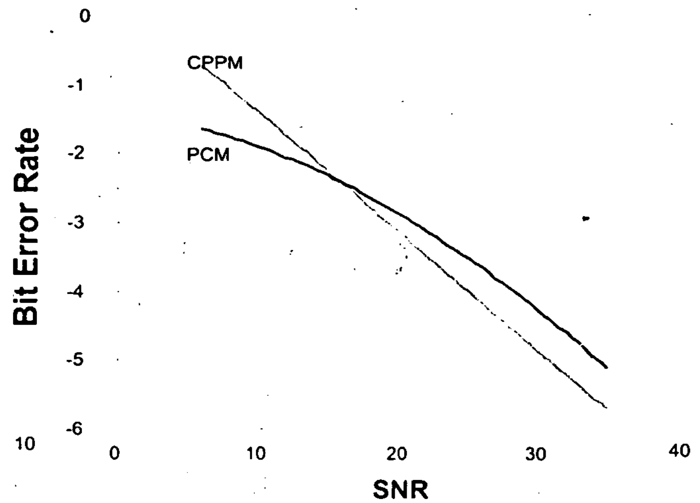

Figure 2. BER Performance Comparison Results for PCM & CPPM Encoding

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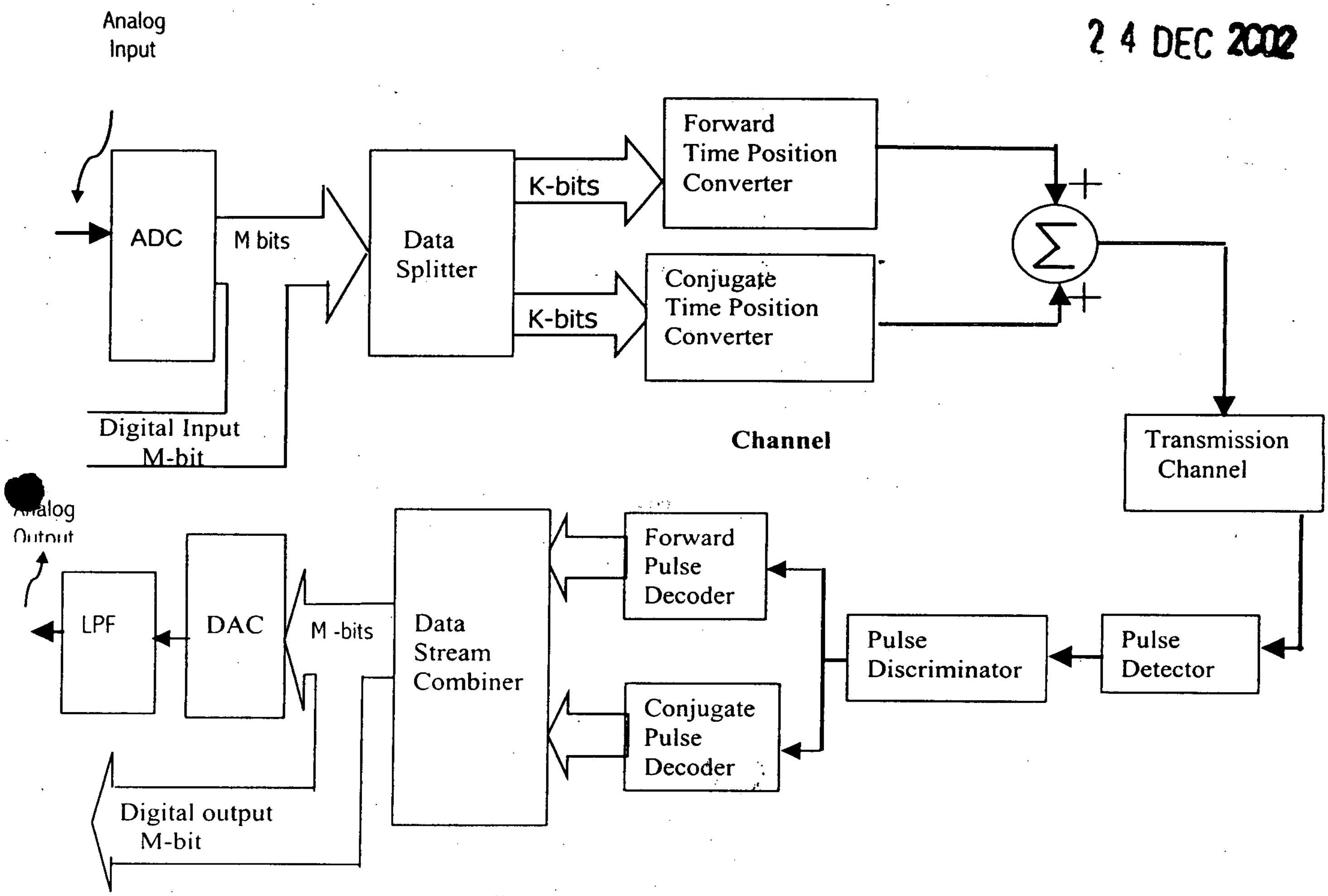

Figure 3. Block Diagram of CPPM Encoder & Decoder System

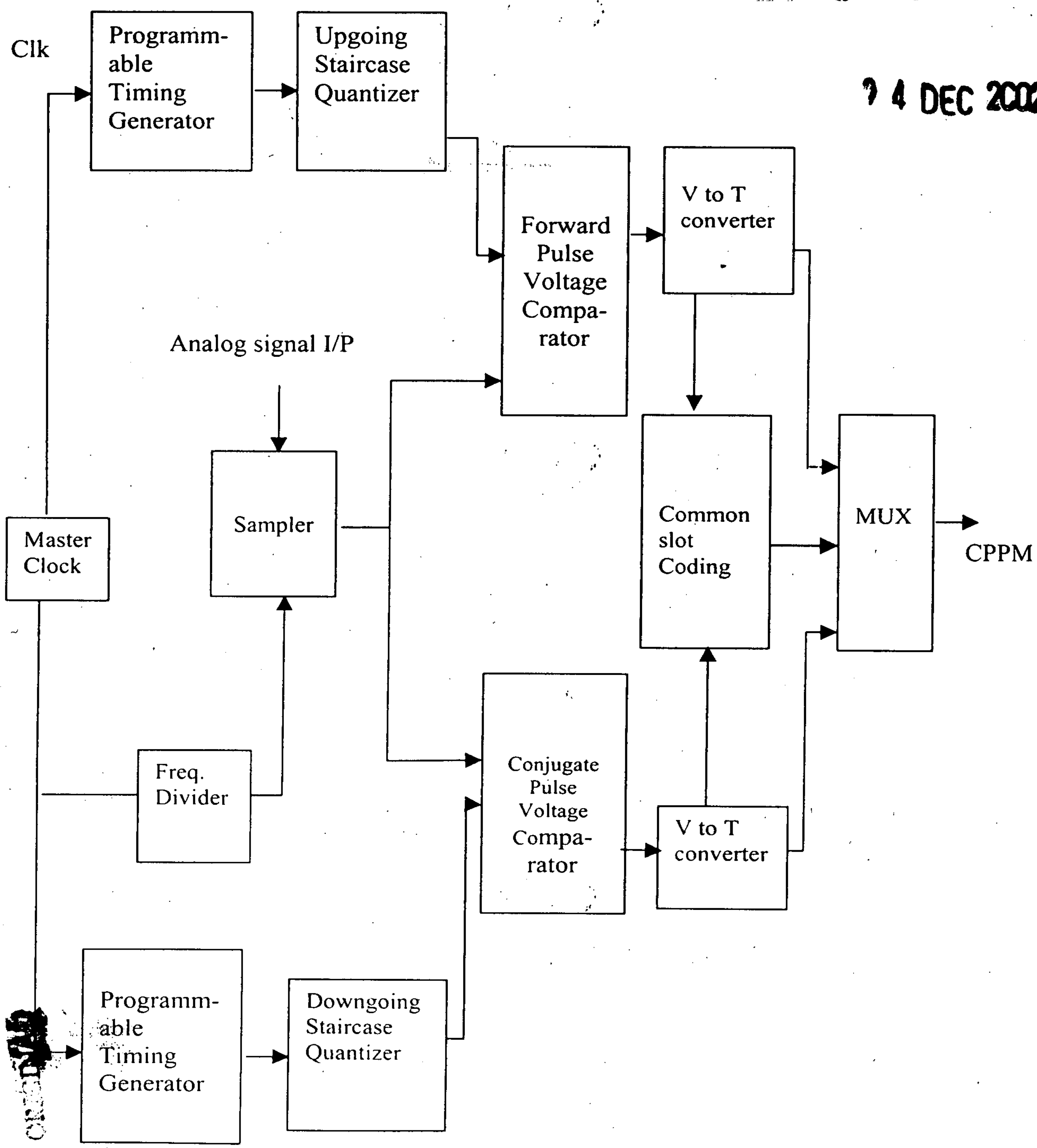

Figure 4 .Block Schematic of Analog Implementation of CPPM Encoder

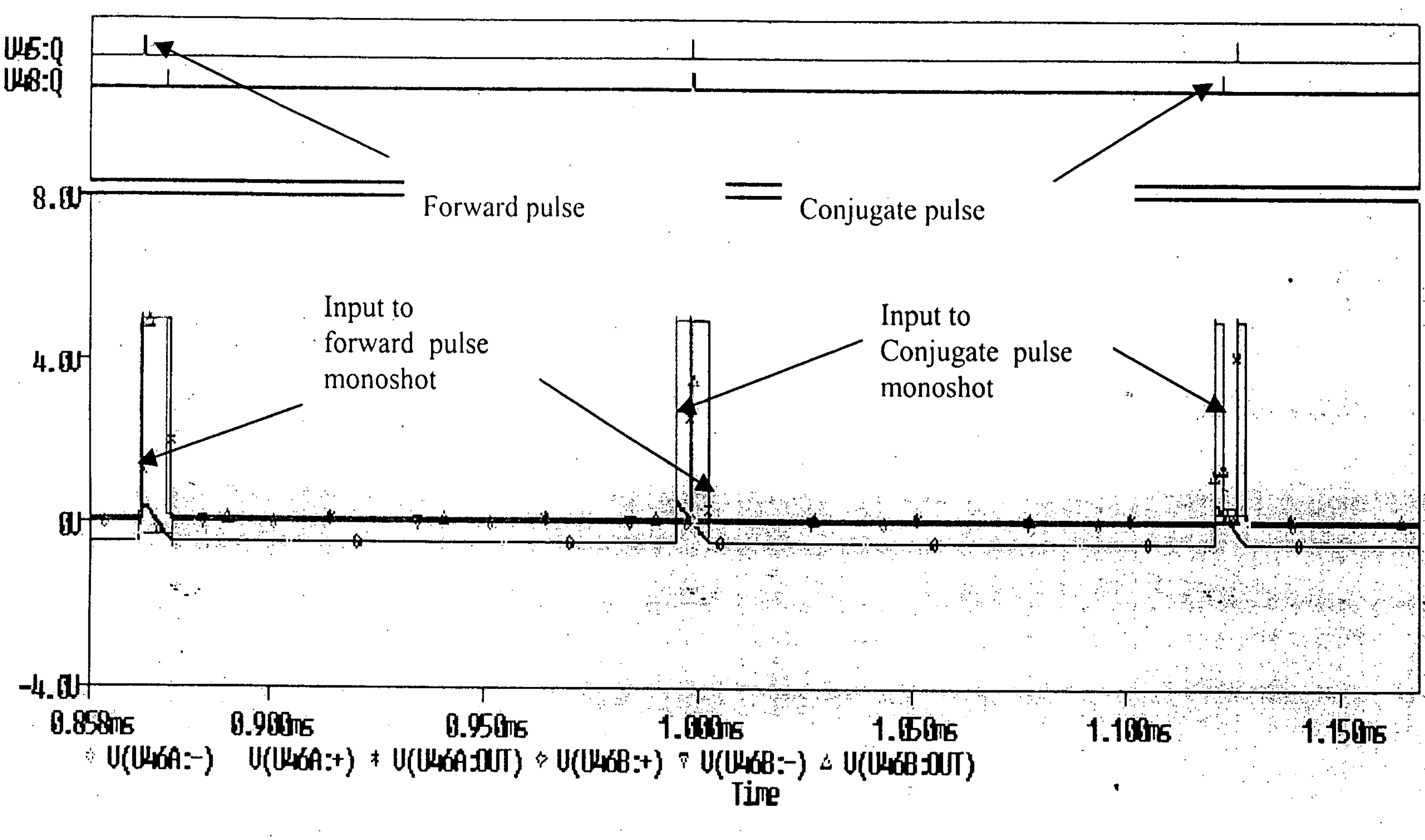

Figure 5. Outputs of the Forward & Conjugate Pulse generator

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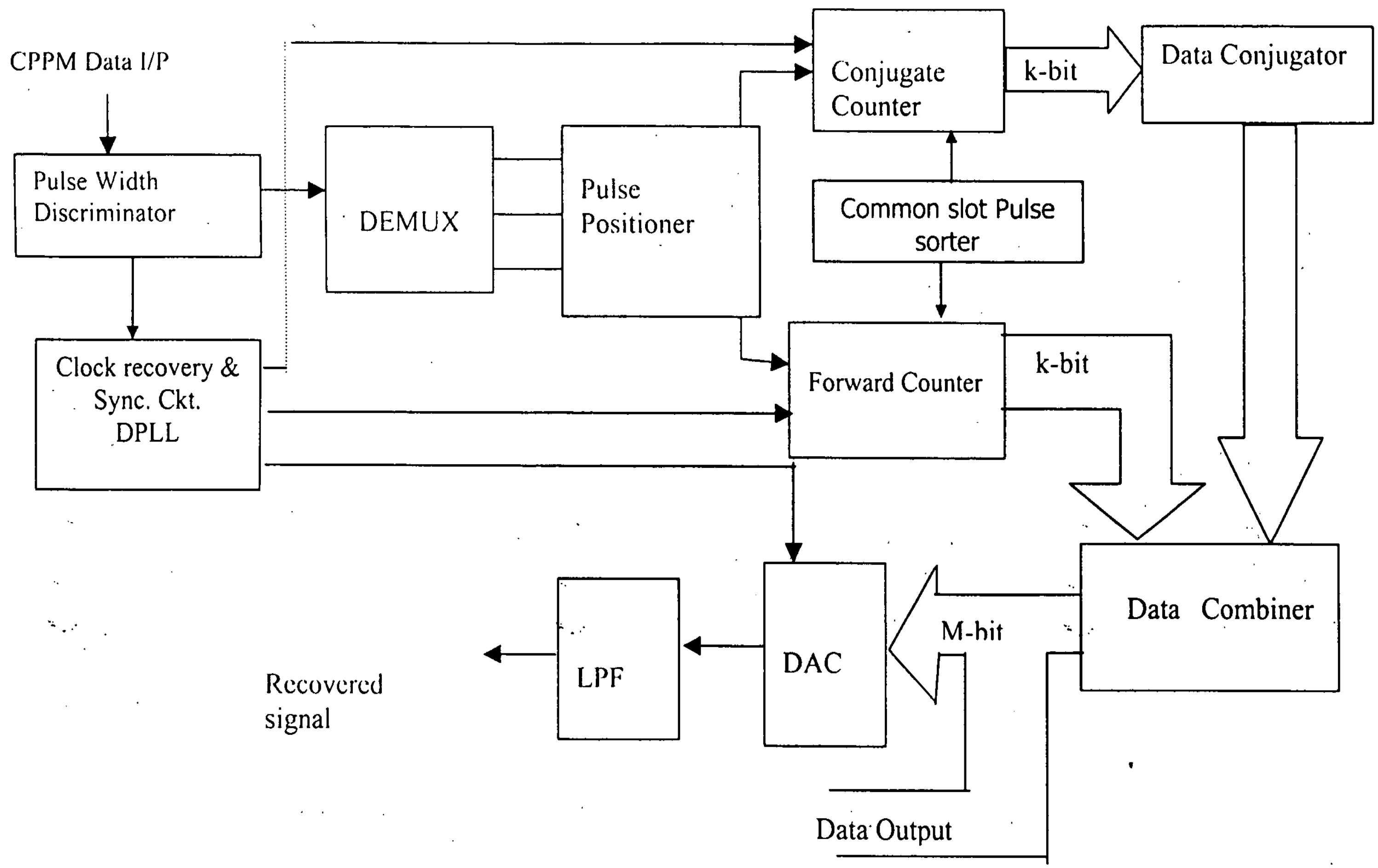

Figure 6. Block Schematic of CPPM Decoder

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